MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

EMF4096 – RADAR SYSTEMS DESIGN AND ANALYSIS

(TE)

6 MARCH 2017
9:00 A.M- 11:00 A.M
(2 Hours)

INSTRUCTION TO STUDENT

1. This examination paper consists of 7 pages including cover page with 4 Questions only.

2. Attempt **ALL** the questions. Each question carry equal marks and distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided. Please number your answers clearly.

Question 1

(a) Briefly describe a basic radar operation. Draw a related diagram to support your answer.

[6 marks]

(b) In a radar system, the radar signal is used to determine the range of a moving vehicle. In this system, an L-band radar is used with an operating frequency of 5000 MHz. The radar cross section is 10 m^2 with maximum range of detection of 220 meters. The antenna directivity is 20 dB with a pulse width of 10 ns. The minimum detectable signal is to be 5×10^{-13} W with unity antenna efficiency. Determine the following:

(i) Pulse repetition frequency (PRF) if range measurement must be unambiguous.

[2 marks]

(ii) Resolution in range.

[2 marks]

(iii) Duty cycle.

[3 marks]

(iv) Average power required to detect a radar cross section vehicle at a maximum range.

[3 marks]

(c) Briefly describe the content of range ambiguity and Doppler ambiguity in a pulsed radar. Derive the expression for maximum velocity and range without ambiguity in terms of pulse repetition frequency (PRF).

[6 marks]

(d) Figure Q1 shows a basic block diagram of radar system. Modify the circuit to become a range detector radar system which consider a fast fourier transform.

[3 marks]

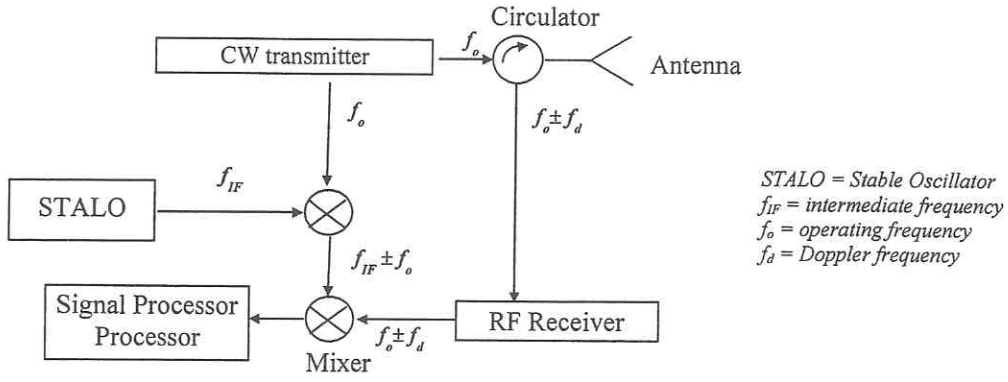

Figure Q1

Continued...

Question 2

(a) In Figure Q2, the modulating frequency is 1.57 kHz, the bandwidth is 180 kHz and the center frequency is 2.4 GHz of Frequency Modulation Continuous Wave (FM-CW) radar with a linear FM modulation. The radar detects a target moving away from the radar, at a range of 40 km with a velocity of 120 m/s.

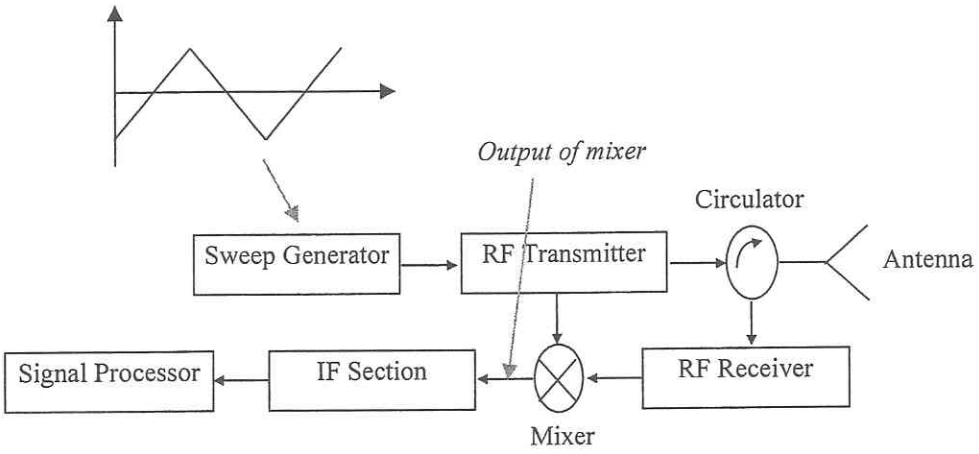

Figure Q2

(i) Analyze the figure for doppler and calculate the frequencies present at the output of the mixer.

[4 marks]

(ii) Design the return echo of the linear Frequency Modulation (FM) signal (frequency vs. time). On your drawing, show the relative position of the transmitted signal.

[3 marks]

(iii) If a sawtooth waveform is used instead of a triangular waveform for the modulation signal, determine the frequencies present at the output of the mixer. Given the modulating frequency of the sawtooth waveform is the same as the triangular waveform.

[3 marks]

Continued...

(b) A synthetic aperture radar instrument has a range resolution of 10 m in the slant range direction and an azimuth resolution of 15 m. Suppose that the pixel spacing is exactly equal to the resolution. Data are processed on the satellite and sent to Earth with one byte representing each pixel.

(i) What is the required bandwidth to achieve a range resolution of 10 m in the slant range if Chirp (Linear FM Pulse) is employed in this Synthetic Aperture Radar (SAR) system.

[4 marks]

(ii) What is the ground range resolution of this instrument if it is operated with an incidence angle of 30°? What is the ground range resolution if the incidence angle is increased to 60° ?

[3 marks]

(iii) At what incidence angle should the radar use to obtain "square"pixels on the ground?

[3 marks]

(c) Provide THREE(3) advantages and disadvantages of using ground penetrating radar (GPR).

[5 marks]

Continued...

Question 3

(a) Define about Radar Cross Section (RCS). State the theoretical definition of the RCS.

[6 marks]

(b) A radar has the following specifications: transmitted power P_t, gain of antenna G, pulse width $\tau = 2$ μs, antenna beam width $\theta = 3°$, and wavelength $\lambda = 5$ cm. The radar illuminates an area as shown in Figure Q3. The range from radar to target is 10 km and the grazing angle, $\psi_g = 30°$. The area has a point target with radar cross section (RCS), $\sigma = 10$ m^2. The point target is surrounded by grass with a backscatter coefficient $\sigma^0 =$ -30 dB.

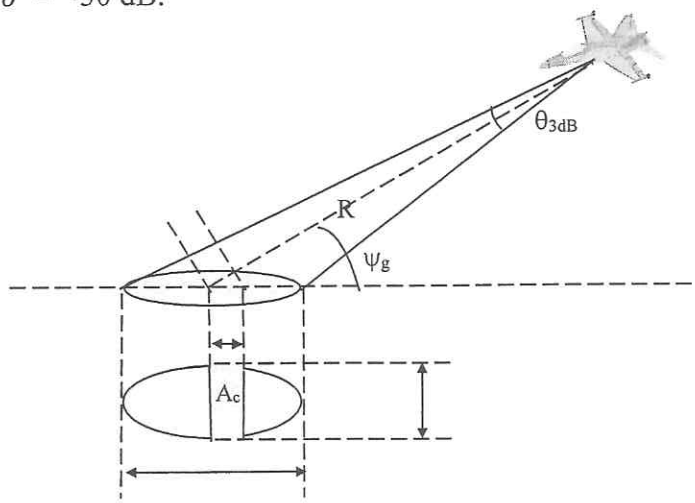

Figure Q3

Calculate the following:

(i) the area illuminated by a single pulse, A_c,

[3 marks]

(ii) the return power solely from the point target,

[2 marks]

(iii) the return power solely from the background A_c, and

[4 marks]

(iv) the signal to clutter (SCR) ratio.

[2 marks]

(c) Consider a monostatic radar operated at 10 GHz. A scattered signal is received from four points on a complex target surface. The first point is 20 km away from the radar, while the other three points are 2 m, 3 m, and 5 m away from the first point on the same line of sight. Find the sum of received signal voltages at time ($t = 20$ second) from the four points, as a function of Σ and r_k. Assuming that all the received signals have identical amplitude $\sqrt{\sigma_o}$=0.2 and phase value of 20 degree. Analyze the received signal voltage in term of amplitude and phase.

[8 marks]

Continued...

Question 4

(a) The overall noise figure and gain of a mixer/IF amplifier in a receiver is $F_2 = 4.5$ dB and $G_2 = 12$ dB, respectively. The noise figure of this combination is to be reduced by cascading it with a low-noise amplifier (LNA) having a gain $G_1 = 13$ dB and noise figure F_1 as shown in Figure Q4(a). What is the requirement on F_1 (in dB) to yield a system noise figure less than F_2?

[4 marks]

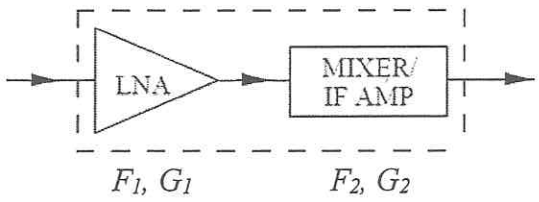

Figure Q4(a)

(b) Figure Q4(b) shows the block diagram of an airborne synthetic aperture radar (SAR) system.

(i) Determine the main purpose of using circulator in this design.

[3 marks]

(ii) Find out the main disadvantage of the circulator if we wish to transmit a high power signal. Modify and create the circuit to address this disadvantage and draw an appropriate figure to illustrate the design.

[6 marks]

(iii) Determine the main function of LNA in the receiver.

[3 marks]

(iv) Determine the main function of the 100 MHz oscillator in this design.

[3 marks]

(v) A 500 MHz Analog to Digital Conversion (A/D) is used to sample the return echo. Find the minimum allowable sampling rate in this design.

[3 marks]

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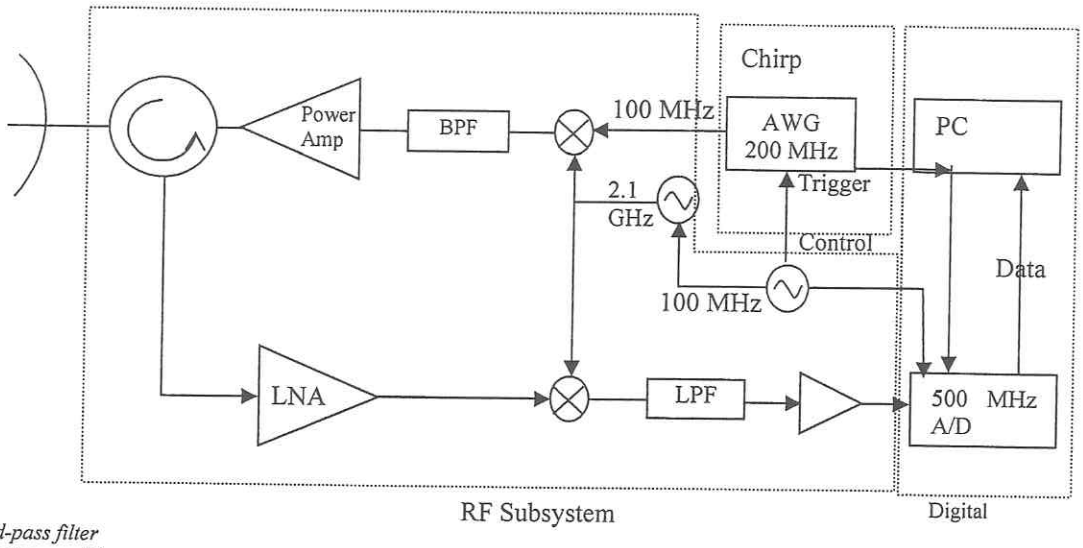

BPF = band-pass filter
LNA= low noise amplifier
LPF= low pass filter
A/D = analog to digital

Figure Q4(b)

(c) Suggest a mode of operation for each of the following typical design cases in radar systems.

(i) case 1 - A Ground-based Surveillance Radar
System level objective: To design a fixed, ground-based surveillance radar to detect the presence and determine the location of aircraft at the longest practical ranges. This type of radar might be used to monitor aircraft as an aid in air-traffic control.

(ii) case 2 - MACRES-MMU Airborne SAR System
System level objectives: To develop an instrument that serves as a test-bed for SAR techniques and its related technologies.

[3 marks]

End of Paper